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| (54) Title: CONTINUOUS CASTING OF STEEL   |    |   |
| (57) Abstract   |    |   |
| A method of and apparatus for continuously downwardly casting steel, in which molten steel (2) is poured into a continuous casting mould (3) and the still molten and/or solidifying steel is subjected after pouring to a helical electromagnetic force field, to obtain a stirring effect. Preferably said stirring is obtained by means of a plurality of electromagnetic coil assemblies (5) located about the steel strand path (4). |    |   |

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TITLE: CONTINUOUS CASTING OF STEEL

This invention relates to the continuous casting of steel, and more particularly to electromagnetic stirring of the still-molten and/or solidifying steel after pouring 5 into a mould.

It has been found desirable to provide such stirring to many grades of cast steel for a number of reasons perhaps the chief of which in general is to achieve homogeneity of at least the major portion of the cross-10 section of the steel strand, and to remove non-metallic inclusion and included gases.

It is an object of the present invention to provide an improved electromagnetic stirring arrangement for use in the continuous casting of steel.

15 According to one aspect of the present invention there is provided a method of continuously downwardly casting steel, including pouring the molten steel into a continuous casting mould and subjecting the still molten and/or solidifying steel after pouring to a helical electromagnetic 20 force field. Such force can be upwardly helical whereby the



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radially outer part of the molten steel spirals upwards and the radially central portion spirals downwards relative to the metal strand, and conversely for a downward helical force.

5        According to another aspect of the present invention there is provided apparatus for the continuous downward casting of steel including a continuous casting mould and electromagnetic stirring means located about the metal strand path adjacent to the mould, the electromagnetic stirring means being adapted to subject still molten and/or 10 solidifying steel to a helical force. Such helical force can be upwards or downwards.

The helical stirring movement of the molten steel of the present invention has useful application with regard to 15 any continuous cast steel, and its value can be exemplified by the continuous casting of aluminium treated steel. Two noteworthy problems in the casting of such steel are the need to avoid retaining inclusions of alumina in the steel as it is cast, and the need to ensure an outer surface layer 20 around the strand free from included gas and entrapped slag.

Previously proposed arrangements for horizontal, rotational, stirring of the steel suffer from the disadvantages, especially in the context of the above-mentioned aluminium treated steel, that inclusions tend to be trapped



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and retained below the surface of the steel by rotating stirring action. In addition, with the commonly used moulds of rectangular plan form, the rotational movement of stirring tends to create turbulence and/or standing waves at the mould corners which severely hinders the removal of inclusions and produces undesirable surface ripples on the strand surface. It is also desirable with this form of stirring to ensure that the stirring force penetrates to the central portions of the steel for adequate stirring throughout, which imposes restrictions on power supply frequencies.

Again previously proposed arrangements for a vertical stirring of the steel suffer from the disadvantage that considerable energy is required to reverse the movement of the molten steel at the top and bottom of the movement pattern, so that excessive power is required for the electromagnetic arrangement to achieve satisfactory stirring movement.

The helical stirring of the present invention enables all of these disadvantages to be overcome.

The electromagnetic stirring may be provided by means of a plurality of electromagnetic coil assemblies located about the steel strand path, each being directed towards the strand path. The coil assemblies may be powered from a



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multi phased (e.g. three phased) electricity supply.

The coil assemblies may be arranged in a series of rings about the steel strand path, adjacent assemblies in successive rings being phase shifted to provide the overall 5 helical force field. The amount of phase shift between successive rings may vary axially of the arrangement so as to provide a varied angle helical field.

Thus in one embodiment the phase shift may be much greater at the upper portions of the stirring means, 10 thereby providing a much more rotational force at the upper and a much more vertical force at the lower end of the steel being stirred. Such an arrangement has been found especially well adapted at avoiding the disadvantages of prior arrangements whilst combining their 15 advantages. The series of rings may be capable of relative rotational adjustment so as to adjust the angle of the helical field. Alternatively or in addition the coil assemblies in successive rings may be connected for switching phase sequences to provide a phase shift to 20 adjust the angle of the helical force field.

Alternatively a shaded pole winding arrangement or skewed winding arrangement can be used for providing the helical force field.



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The electromagnetic stirring means may be disposed about the casting mould itself, or alternatively or additionally may be provided about the strand path below the mould.

5 We believe the arrangement of the invention is particularly useful in casting steel of square sections of less than about 200mm. width.

10 The helical stirring will be greatly facilitated if the electromagnetic body force can be made small on or near the strand axis by choosing an electromagnetic field configuration with a minimum of 2 pole pairs circumferentially, and the smallest pole pitch axially commensurate with achieving optimum performance.

15 With strands in the size range 150-200mm. (square section widths) the relative value of input electrical energy is preferably of the order, between circumferential and axial of 0.2. This ratio preferably decreases for smaller sizes of strand and increases for larger sizes.

20 In order that the invention may be more readily understood, one embodiment thereof will now be described by way of example with reference to the accompanying drawing in which:-

Figure 1 is a diagrammatic sectional elevation of continuous steel casting apparatus according to the



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invention; and

Figure 2 is a section of the line II - II of  
Figure 1.

Referring to the drawings, 1 represents a tundish or similar vessel containing molten steel, located above and pouring steel 2 into a continuous casting mould 3. As will be clearly seen from Figure 2, the mould 3 is shown, for ease of illustration, as being of circular plan. In practice, however, the mould would often be of a square or rectangular section. The mould is provided in the usual way with a water cooling annulus 10.

In the usual manner, the steel 2 is withdrawn from the mould as a solidifying strand 4 for subsequent processing.

Located about the mould with annular end plates 8 are six sets of annular stator blocks 7 arranged one above the other, each block comprising six coil assemblies 5 disposed equi-angularly about the mould 3, each assembly 5 being provided with electrical windings (not shown).

With a three-phase supply it will be appreciated that the six assemblies 5 in each block 7 may be connected to give a two pole or a four pole arrangement.

Water cooling may be provided for the electromagnetic



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stirring means by means of interconnected water channels 6 disposed between and around assemblies 5. Water inlets 11 and outlets 12 are provided. Alternatively, water cooling may be provided by means of hollow windings for the 5 assemblies 5 through which water is forced.

By means of suitable phase shifting between successive stator blocks 7, by electrical connecting and/or by mechanical alignment, a helical force field may be produced having a predetermined upward angle within the mould. Since 10 the field is strongest adjacent the outer wall of the mould the field will have the effect of creating an upward helical stirring of metal around the radially outer portions of the liquid metal, and a returning downward helical in the radially inner portions of the liquid metal.

15 It will be understood that any required length of stirring arrangement can be provided by using the required number of coil assemblies 5.



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CLAIMS

- 1 A method of continuously downwardly casting steel, including pouring the molten steel into a continuous casting mould and subjecting the still molten and/or solidifying steel after pouring to a helical electromagnetic force field.
- 2 A method as claimed in Claim 1 wherein the electromagnetic force field is helical upwardly whereby the radially outer part of the molten steel spirals upwards and the radially central portions spirals downwards relative to the metal strand.
- 3 A method as claimed in Claim 1 or 2 wherein the angle of the helix of the electromagnetic force field is varied axially of the casting mould.
- 4 A method as claimed in Claim 3 wherein the angle of the helix compared to the axis of the casting mould is greater at the upper end of the steel being subjected to the helical electromagnetic force field.
- 5 A method as claimed in any one of the preceding Claims, wherein the steel is subjected to the helical electromagnetic force field within the casting mould.



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- 6         Apparatus for the continuous downward casting of steel including a continuous casting mould and electromagnetic stirring means located about the metal strand path adjacent to the mould, the electromagnetic stirring means being adapted to subject still molten and/or solidifying steel to a helical force.
- 7         Apparatus as claimed in Claim 6 wherein the electromagnetic stirring means is adapted to subject the steel to an upward helical force.
- 8         Apparatus as claimed in Claim 6 or 7 wherein the electromagnetic stirring is provided by means of a plurality of electromagnetic coil assemblies located about the steel strand path.
- 9         Apparatus as claimed in Claim 8 wherein the coil assemblies are powered from a multi-phased electrical supply.
- 10        Apparatus as claimed in Claim 8 or 9 wherein the coil assemblies may be arranged in a series of rings about the steel strand path, adjacent coil assemblies in successive rings being phase shifted to provide the overall helical force field.



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- 11       Apparatus as claimed in Claim 8, 9 or 10 wherein the coil assemblies in each ring are provided with at least two pole pairs disposed circumferentially.
- 12       Apparatus as claimed in any one of Claims 8 to 11 wherein the phase shift between successive rings of coil assemblies is variable.
- 13       Apparatus as claimed in Claim 12 wherein the greatest phase shift between successive rings occurs adjacent the upper end of the stirring means.
- 14       Apparatus as claimed in Claim 12 or 13 wherein adjustability of phase shift is achieved by providing the series of rings of coil assemblies with capability for rotational movement.
- 15       Apparatus as claimed in Claims 12, 13 or 14 wherein the coil assemblies in successive rings are connected for switching phase sequences whereby to provide an adjustable phase shift there between.
- 16       Apparatus as claimed in any one of Claims 6 to 11 wherein the electromagnetic stirring means comprises a shaded pole winding arrangement or skewed winding arrangement for providing the helical force field.



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17       Apparatus as claimed in any one of Claims 6 to 16  
wherein the electromagnetic stirring means is disposed  
about the casting mould itself.

18       A method of continuously downwardly casting steel  
substantially as hereinbefore described with reference to  
the accompanying drawing.

19       Apparatus for the continuous downward casting of  
steel substantially as shown in and as hereinbefore  
described with reference to the accompanying drawings.



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FIG. 1.

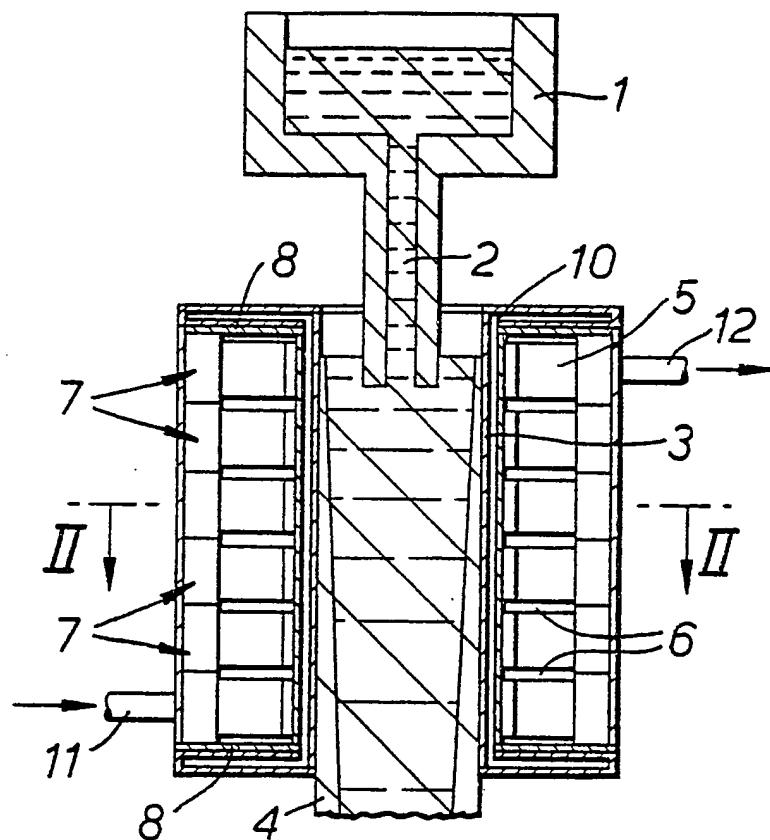
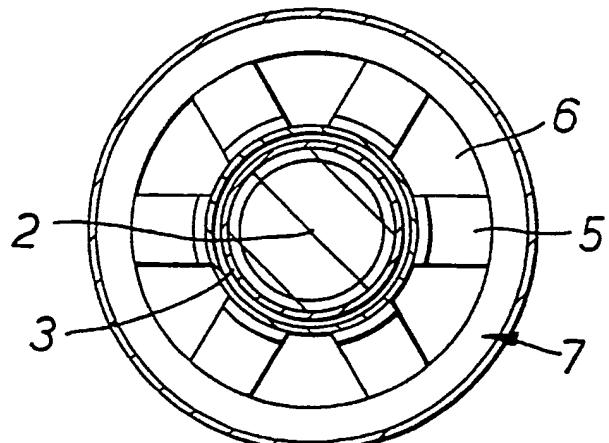


FIG. 2.



# INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 80/00047

## I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) <sup>3</sup>

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. <sup>3</sup>: B 22 D 11/12; B 22 D 11/10; B 22 D 27/02

## II. FIELDS SEARCHED

Minimum Documentation Searched <sup>4</sup>

| Classification System   | Classification Symbols                   |
|---|--|
| Int.Cl. <sup>3</sup>  | B 22 D 11/12; B 22 D 11/10; B 22 D 27/02 |
| Documentation Searched other than Minimum Documentation<br>to the Extent that such Documents are Included in the Fields Searched <sup>5</sup> |  |

## III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>14</sup>

| Category <sup>15</sup> | Citation of Document, <sup>16</sup> with indication, where appropriate, of the relevant passages <sup>17</sup>  | Relevant to Claim No. <sup>18</sup> |
|------------------------|---|-------------------------------------|
| X                      | FR, A, 2379339, published September 1, 1978<br>see page 5, lines 32-40; page 6, line<br>1; page 7, lines 27-35; claims 4,5,<br>Asea Aktiebolag<br>--  | 1,6,7,8,9                           |
| P                      | EP, A, 0005676, published November 28, 1979<br>see page 3, lines 34-40; page 4, lines<br>1-6; page 5, lines 27-37; claim 1,<br>Compagnie Electro Mecanique<br>corresponding to FR, A, 2426516 | 1,2,6,7,8,9                         |
| A                      | FR, A, 1140200, published July 16, 1957<br>see page 1; left-hand column, lines<br>30-40, Bohler<br>-----  |                                     |

\* Special categories of cited documents: <sup>13</sup>

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"X" document of particular relevance

## IV. CERTIFICATION

Date of the Actual Completion of the International Search <sup>19</sup>

9th May 1980

Date of Mailing of this International Search Report <sup>20</sup>

21st May 1980

International Searching Authority <sup>1</sup>

European Patent Office

Signature of Authorized Officer <sup>20</sup>

G.L.M. Kruydenberg